

AMENDMENTS TO THE SPECIFICATION

Please replace the paragraph beginning at page 3, par[0009], with the following rewritten paragraph:

-- Another embodiment of the present invention provides a pixel-registered photo detector array. The array includes one or more detector layers of semiconductor material. Each detector layer is between contact layers of semiconductor material, thereby defining a stack of layers having a front side and a back side. A waffle-type light-coupling grating is formed on the backside of the stack, and has a pattern of ~~holes~~ wells that reflects a substantial portion of light coming into the array so as to disperse that light through the one or more detector layers, thereby facilitating absorption. The pattern of the waffle-type light-coupling grating can be configured with a geometry optimized for a center wavelength of interest, and an orientation ranging from about 20 to 70 degrees. In one such embodiment, the geometry includes a ~~hole~~ well depth of about one quarter wavelength of the center wavelength of interest, and a spacing between the ~~holes~~ wells of about the center wavelength of interest. --

Please replace the paragraph beginning at page 4, par[0012], with the following rewritten paragraph:

-- The pattern of the light-coupling grating can be a waffle-type grating and have a geometry that includes a ~~hole~~ well depth of about one quarter wavelength of a center wavelength of interest, and a spacing between the ~~holes~~ wells of about the center wavelength of interest. The pattern of the light-coupling grating may have an orientation, for example, of about 45 degrees. Other orientations, however, can be used here as well, such a 0 degrees or 70 degrees. The array can be configured with a plurality of detector layers, each having a different light absorption versus wavelength response curve thereby enabling a multicolor photo detector. Each of the one or more detector layers can be, for example, about one micron or less in thickness. As previously indicated, each of the contact layers can be electrically coupled to a respective electrical contact on the backside, thereby facilitating hybridization where the array is connected to a substrate configured with supporting electrical circuitry.

Please replace the paragraph beginning at page 5, par[0027], with the following rewritten paragraph:

-- Embodiments of the present invention provide various structural features of a QWIP that enhance its optical coupling to improve absorption capability and efficiency. A waffle-type light-coupling grating having a pattern of etched ~~holes~~ wells operates to improve absorption by preventing photons from bouncing out of the detector sensing areas. Parameters of the grating, including its orientation, pitch, and depth, can be adjusted to optimize specific color detection. --

Please replace the paragraph beginning at page 12, par[0050], with the following rewritten paragraph:

-- The light-coupling grating pattern 60 may be configured in a number of ways. For example, the light-coupling grating 60 can be a grid of posts or wells, wherein the pitch of the post/wells is one wavelength of the center frequency of interest, and the area of the grid lines is about equal to the area of the square posts/~~holes~~wells. The pattern 60 may be oriented diagonally with respect to the major edges of the pixel so that the refracted light is directed towards the pixel edges at other than at right angles. The features of the pattern 60 may be etched, where the etch depth is about one quarter wavelength of the center frequency of interest. The top or final contact layer and the edges of the detector layers 20 and 40 of each pixel may be reflectively coated for containing light within the pixel, thereby causing that light to be reflected endlessly from edge to edge within the plane of the detector layers 20 and 40. --

Please replace the paragraph beginning at page 12, par[0051], with the following rewritten paragraph:

-- Figures 6a and 6b each show a partial perspective view of a light-coupling grating pattern configured in accordance with an embodiment of the present invention. In one particular application, the top or unetched level 62 of light-coupling pattern ~~60~~ 70 or 80 is first treated with an AuSnAu deposition or other suitable coating for electrical bonding of a contact pad. The full pattern ~~60~~ 70 or 80 is then coated with a gold mask, assuring that sidewalls 64 and lower, etched levels 66 of the pattern are directly gold coated to achieve a smoother, more reflective quality with respect to the interior side of the coating. Note that the AuSnAu deposition is limited to the

top surface 62 where bonding is necessary, because tin (Sn) tends to permeate the surface of the semiconductor material, leaving a rough texture to the coating interface on the contact layer that degrades the reflective properties of the coating. Further note that the bump or contact 51 for contact layer 50 (which is the top or final contact layer of the QWIP structure) is set on areas 62, the upper or unetched level of pattern ~~60~~ 70 or 80. --

Please replace the paragraph beginning at page 13, par[0052], with the following rewritten paragraph:

-- The pixel edges of the detector layers 20 and 40 can also be gold coated to reflect the refracted light vectors repeatedly back into the detector layers 20 and 40 for maximum exposure of the detector layer material to the available light. The thin layers of the QWIP structure, light-coupling pattern ~~60~~ 70 or 80, and associated reflective coatings create in effect what one might refer to as an open face "photon-in-a-box" in which light enters the open face, is refracted at right angles off the backside of the box, and is hence reflected from side to side within the box. --

Please replace the paragraph beginning at page 13, par[0053], with the following rewritten paragraph:

-- As can be seen in Figure 6a, a square post pattern ~~60~~ 70 can be used. This post-like pattern 70 may be etched to remove grid lines 66, thereby leaving the upper/unetched level square posts 62 in relief. Alternatively, lower/etched level square wells 66 may be etched thereby leaving the grid lines 62 in relief, as shown in the waffle-like grating 80 of Figure 6b. The resultant surface area of each post or well for a given pattern is about equal, as well each post height or well depth so as to provide a two dimensional grating. Note, however, that irregular grating patterns having varied post height or well depths can also provide benefits as will be apparent in light of this disclosure. --

Please replace the paragraph beginning at page 13, par[0054], with the following rewritten paragraph:

-- The refraction effect of a square pattern on light entering the detector tends to be bi-directional, oriented with the lines of the pattern. As such, the pattern can be diagonally oriented

with respect to the edges of the pixel 90 as shown in Figure 7a, so planar light vectors are initiated at angles other than perpendicular to the edges of the pixel 90. This further enhances edge reflection properties within the detector layer, bouncing the light vectors around the photon box rather than straight back and forth between opposing sides. --

Please replace the paragraph beginning at page 13, par[0055], with the following rewritten paragraph:

-- Figures 7a-f illustrate various orientations and patterns of light-coupling gratings configured to improve specific color absorption in accordance with embodiments of the present invention. Each pattern can be used in a post-type 70 or a waffle-type grating 80. However, as shown in Figures 8a-d, the quantum efficiency performance of optimized waffle-type gratings 80 exceeds that of the conventional post-type gratings 70. Grating parameter variables include, for example, pitch or spacing between etched and relief portions, duty cycle, polarity (e.g., post/waffle), orientation (e.g., 20° to 70°), depth (e.g., 5 depths, 0 to 1 μm), and metallization (e.g., photon-in-a-box with gold). --

Please replace the paragraph beginning at page 14, par[0057], with the following rewritten paragraph:

-- Figure 8a compares the responsivity spectra of a 8.3 μm QWIP FPA at a +4 volts bias between a conventional post-type light-coupling pattern 70 (i.e., square post oriented at 0°) and a waffle-type light-coupling pattern 80 oriented at 45°. Figure 8b demonstrates the improvement in quantum efficiency provided by the waffle-type grating 80 embodiment. Similarly, Figure 8c compares the responsivity spectra of a 11.2 μm QWIP FPA at a -4 volts bias between a conventional post-type light-coupling pattern 70 (i.e., square post oriented at 0°) and a waffle-type light-coupling pattern 80 oriented at 45°. Figure 8d demonstrates the improvement in quantum efficiency provided by the waffle-type grating 80 embodiment. --

Please replace the paragraph beginning at page 14, par[0058], with the following rewritten paragraph:

-- As can be seen, a waffle grating 80 oriented at approximately 45° provides a significant performance improvement. In particular, the quantum efficiency for the 8.3 μm QWIP FPA is as high as about 16%, and about 40% for the 11.2 μm QWIP. In addition, the conversion efficiency for the 8.3 μm QWIP FPA is as high as about 8%, and about 20% for the 11.2 μm QWIP. Thus, a waffle grating 80 etched into each QWIP pixel improves light absorption by quantum wells, relative to a post grating 70. Rotating the waffle grating 80 (e.g., 20° to 70°) further improves optical coupling by minimizing lateral light leakage out of the pixel 90. Note, however, that an unrotated waffle-type grating 80 (oriented at 0°) is also a viable embodiment of the present invention. Further note that a rotated post-type grating 70 (e.g., oriented between about 20° to 70°) is also a viable embodiment of the present invention. --

Please replace the paragraph beginning at page 21, par[0067], with the following rewritten paragraph:

-- A QWIP structure is disclosed that is configured with enhanced optical coupling to improve absorption capability and efficiency. A waffle-type light-coupling grating having a pattern of etched ~~holes~~ wells operates to improve absorption by preventing photons from bouncing out of the detector sensing areas. A post-type light coupling grating can also be used. Parameters of the grating, including its orientation, pitch, and etch depth, can be adjusted to optimize specific color detection. The grating can include a hybrid metal layer including both ohmic and reflective qualities to further improve quantum and conversion efficiency. A “photon-in-a-box” configuration is also disclosed, where sides of the QWIP sensing areas are coated with reflective metal to further inhibit the escaping of photons. The material design and number of quantum wells per QWIP can be selected so as to exploit the avalanche effect, thereby increasing device responsivity. --